Comment on "Evidence for Narrow Baryon Resonances in Inelastic *pp* Scattering"

In a recent Letter [1], Tatischeff *et al.* have claimed evidence for 3 neutral baryon resonances N^* between the nucleon and the $\Delta(1232)$. Two of these have masses $M = 1004$ MeV and 1044 MeV below $m_N + m_\pi$ and thus their widths ($\Gamma = 4$ to 15 MeV) are radiative. The third resonance ($M = 1094$ MeV) also might have a radiative decay. All the resonances have to contribute to Compton scattering on the nucleon and result in peaks at energies $E_\gamma = 68$, 112, and 169 MeV, respectively, which were never observed on protons [2–5] or neutrons [6,7] loosely bound in the deuteron. Since constraints of this type are very sensitive and were not analyzed in the Letter, we give estimates below. For other theoretical constraints see Ref. [8].

The differential cross section of γN scattering near the resonance peak must be equally visible at any scattering angle. For $j = 1/2$ it is just isotropic. For $j = 3/2$, the angular distribution typically follows $\frac{1}{8}(3\cos^2\theta + 7)$ if a dipole ($E1$ or $M1$) transition dominates, and is rather flat with $\leq 25\%$ deviations from an average magnitude. The differential cross section averaged over angles and over a center-of-mass energy interval ΔW reads

$$\langle \frac{d\sigma_{\gamma N}}{d\Omega_{\rm cm}} \rangle = \frac{\pi X}{4E^2_{\gamma\,\rm cm}} = aX \times \begin{cases} 7.6, & M = 1004 \text{ MeV} \\ 3.0, & M = 1044 \text{ MeV} \\ 1.5, & M = 1094 \text{ MeV} \end{cases}$$

where $a = 10^7$ nb/sr, $X = (j + \frac{1}{2})(\Gamma/\Delta W)\mathrm{Br}^2_\gamma$, and the radiative branching $\mathrm{Br}_\gamma = 1$ for the first two states. (Here we assume $\Delta W \gg \Gamma$, which we show to be a very good approximation.)

The data of Ref. [3] on γp scattering near $E_\gamma = 68$ MeV have a scale of 10−15 nb/sr, with variations of at most 3 nb/sr in energy bins of $\Delta W \simeq 5$ MeV. Therefore, a p^* resonance near 1004 MeV must have $X < 4 \cdot 10^{-8}$ and the total width $\Gamma < 0.2$ eV seven orders of magnitude less than Tatischeff *et al.* have reported.

If we assume $j = 1/2$, the interaction leading to the transition $\gamma N \leftrightarrow N^*$ is dipole M1 (or E1 depending on the parity of the resonance), $H_{\rm eff} = -e\vec{H} \cdot \vec{\sigma} D$. Here D is a transition magnetic (or electric) dipole moment and $e^2/4\pi = \alpha = 1/137$. The radiative width of the N^* then reads $\Gamma_\gamma = 4\alpha E^3_{\gamma\,\rm cm} D^2$. With $\Gamma_\gamma < 0.2$ eV, the transition dipole moment of $N^*(1004)$ is $D < 1.0 \cdot 10^{-3}$ fm, that is at least three orders of magnitude smaller than the size of the nucleon. The wave function of such a resonance would have a very small overlap with the nucleon wave function, and it would be very difficult to produce N^* with ordinary beams.

In the same way, data of Ref. [4] give an upper limit $\Gamma < 1.6$ eV for the $p^*(1044)$ resonance, and data of Ref. [5] give $\mathrm{Br}^2_\gamma \Gamma < 7$ eV for the $p^*(1094)$.

Information pertaining to neutral states can be obtained, in principle, via the reaction $\gamma d \to \gamma np$ in the kinematics of quasi-free γn scattering. Rose *et al.* [6] have measured the cross section for neutron knockout in inelastic γd scattering, $\gamma(d, \gamma' n)p$, for quasi-free kinematics at energies around $E_\gamma = 110$ MeV (the energy bin was about 40 MeV). Although the authors did not extract the differential cross section for γn scattering, they found agreement between the double differential cross section $d^2\sigma/d\Omega_{\gamma'} d\Omega_n$ and the theoretical calculation by Levchuk *et al.* [9], obtained with the same kinematical conditions.

Since the observed cross section is dominated by the γn subprocess, rescaling arguments can be used to obtain experimental estimates for the differential cross section of γn scattering. This leads to the following result:

$$\frac{d\sigma_{\gamma n}}{d\Omega_{\rm lab}} = \begin{cases} 2.5 \pm 0.7 \text{ nb/sr}, & 90^\circ \\ 3.2 \pm 0.7 \text{ nb/sr}, & 135^\circ \end{cases}$$

at $E_\gamma = 110$ MeV. Accordingly, we find $X < 1.5 \cdot 10^{-7}$ and hence $\Gamma < 6$ eV for the $n^*(1044)$ state.

From data on elastic γd scattering at 69 MeV [7] one can find the following bound for the total widths of the $p^*(1004)$ and $n^*(1004)$ states: $\Gamma_p + \Gamma_n \lesssim 1.5$ eV.

Thus, the states of $M = 1004$ and 1044 MeV with the properties given in Ref. [1] are completely excluded by Compton scattering data. The same is valid for the 1094 MeV state unless its branching ratio is anomalously suppressed in comparison with a typical value of $\mathrm{Br}_\gamma \sim \alpha$.

It is worth mentioning that a previous search [10] for isospin 3/2 resonances in this mass region gave a null result.

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